2

Ecosystem Services Linked to Livelihoods and Well-Being in the Ganges-Brahmaputra-Meghna Delta

Helen Adams, W. Neil Adger, and Robert J. Nicholls

2.1 Introduction

This chapter addresses one of the main aims of the research that lies at the core of intellectual effort to discern how ecosystem services relate to poverty and its alleviation, to provide an assessment of whether and how development efforts for poverty reduction can be achieved alongside maintaining and building the integrity of the environment and ecosystem services.

H. Adams (✉)
Department of Geography, King's College London, London, UK

W. Neil Adger
Geography, College of Life and Environmental Sciences,
University of Exeter, Exeter, UK

R. J. Nicholls
Faculty of Engineering and the Environment and Tyndall Centre for Climate Change Research, University of Southampton, Southampton, UK

R. J. Nicholls et al. (eds.), *Ecosystem Services for Well-Being in Deltas*,
https://doi.org/10.1007/978-3-319-71093-8_2

This dilemma is common at all scales and in all ecoregions of the world and has been at the heart of sustainable development challenges and discourses for decades, as described briefly in Chap. 1. The challenges and trade-offs between development and maintaining a healthy environment have been recognised and analysed from all major theoretical perspectives. This includes issues of environmental entitlements (Leach et al. 1999), dilemma of the commons (Ostrom 1990), capability approaches and the development of changing livelihoods based on capital (Scoones 1998).

Policies focused on agricultural reform and the green revolution have played a major part in alleviating poverty, raising living standards and increasing food security across the developing world throughout later twentieth century (Hartmann and Boyce 1983; Hayami and Kikuchi 2000) but have simultaneously putting pressure on the underlying ecosystem resource. As such, there is a rich body of theory on the relationship between poor, natural resource-dependent people and their environment that comes to startlingly different conclusions regarding the causes of persistent poverty. These theoretical approaches include entitlement theory (Leach et al. 1999), political ecology (Robbins 2011), resilience theory (Gunderson and Holling 2002), social vulnerability (Adger 1999) and governmentality (e.g. Agrawal 2005).

The research findings reported in this book consider multiple perspectives. They draw first on new insights into the role of the environment as a set of ecosystem services and on new knowledge on environmental and ecological processes within marine, coastal and aquatic environments (described in Chap. 1). The analysis then contextualises that emerging knowledge within development trajectories and interventions for Bangladesh and South Asia. In doing so, it is possible to demonstrate how and whether these ecosystem service approaches provide new directions and insights into the struggle to promote well-being and sustainability. Third, the analysis draws on a wide range of perspectives on what constitutes well-being and poverty to expand the definition of poverty alleviation beyond maximising income. Finally, it places systems thinking at the core of the research, integrating knowledge from multiple disciplines across time and space to evaluate the implications of future interventions for ecosystem services, associated livelihoods and human well-being.

The analysis in this book therefore focuses on the interactions between ecosystem services and social dynamics, both in the present and potentially in the future. As a result, five key results emerge and are discussed in turn: (i) social mechanisms vary with bundles of ecosystem services to create defined social-ecological systems, (ii) subjective and material well-being indicators vary with social-ecological system, (iii) the nature of the interaction between subjective and material well-being and ecosystem services varies over time, (iv) trade-offs exist between different social-ecological systems and parallel flows of labour and (v) ecosystem services for well-being must be contextualised within changing rural economies.

2.2 Key Findings from Systems Perspectives on Well-Being and Ecosystem Services

The integrated multi-method approach demonstrates that the relationship between ecosystem services and well-being in coastal Bangladesh is highly contingent and differentiated a result of its distinct social-ecological systems (see Chap. 22). Hence, the focus shifts to understanding how ecosystem services can reduce particular types of poverty for specific groups of people over different timescales.

Rural livelihoods are diverse over space and time, and populations rely on more than one provisioning ecosystem service for their income. Ecosystem services commonly occur in bundles (sets of services that repeatedly appear together) and as such certain groups of services are more accessible than others. The adoption of a social-ecological system approach allows diversification of ecosystem service use to be considered, including being dependent on a subsidiary service in a particular zone (e.g. fishing in an agricultural area) (Sect. 2.2.1). Thus, the probability of being poor varies in space with the available bundles of ecosystem services and proximity to certain geographical features such as the coast or major rivers, or access to roads and cities.

The ability of ecosystem services to create well-being is dynamic and path dependent. Current productivity is a result of policy decisions made regarding infrastructure (e.g. coastal embankments) and the prioritisation

of ecosystem services (e.g. monoculture rice agriculture versus open access fisheries) which has implications for future benefits. For example, high levels of shrimp monoculture productivity are unsustainable where supporting services have already been eroded by high salinity, but are resilient against reversal due to sea-level rise and the near impossibility of large scale desalination of soil (Sect. 2.2.3).

This example also highlights trade-offs between different bundles of ecosystem services across time and space, affecting the provision of benefits to the poorest in rural settings. There has been a steady concentration of ecosystem services into agriculture and aquaculture that tend to benefit those with access to land, to the detriment of open access provisioning services (e.g. fishing) and supporting services such as water quality—that are crucial for the poor. Thus, while ecosystem services are alleviating poverty through the export of shrimp, for example, this approach is neither sustainable nor pro-poor (Sect. 2.2.4).

However, it is crucial to note that existing inequalities within villages that keep the poor trapped in poverty are unlikely to be redressed by ecosystem service-based interventions, especially in a monetised rural economy that is becoming progressively less dependent on local ecosystem services (see Chaps. 12 and 28). For example, currently, a third of the population studied in this research have no access to ecosystem services at all for income, and even fewer have access to land to cultivate (Sect. 2.2.5).

Finally, the opportunities and losses occurring in the region should be analysed in the context of the market economy. While traditional ecosystem-based and social mechanisms of survival and subsistence have been undermined by market-based approaches, many of the opportunities that could emerge—namely, more sophisticated off-farm activities—have not materialised. Thus, while ecosystem services are increasingly monetised, the subsistence activities they undermine have not been replaced. Migration to alternative labour markets and debt tend to fill any gaps in income.

The means by which ecosystem services generate well-being in Bangladesh is therefore in transition, moving from subsistence-based approaches that provide safety nets, but without the potential for poverty

alleviation, to market-based approaches where economic benefits are greater but tend to accrue to fewer people living in these rural areas and those who already have resources. Concurrently, rural livelihoods have become less and less dependent on local ecosystem services, with off-farm work and migration to urban areas or alternative labour markets contributing a growing share to household incomes.

2.2.1 New Analysis of Ecosystems as Critical to Poverty and Development

The approach adopted in this research to understanding poverty-environment linkages is novel in four key ways. First, it takes an integrated, systems approach that considers interactions, feedbacks and trade-offs, which is missing in most analyses (Dempsey and Robertson 2012). Second, the research considers many different epistemic approaches including the consideration of poverty-environment linkages from multiple methodological and theoretical standpoints (Nicholls et al. 2016). Some of these are integrated within the modelling framework, while others provide richness and understanding to the findings. Third, the analysis is future oriented. It is not sufficient to understand present ecological determinants of well-being, without understanding the capacity for these systems or services to continue to generate well-being into the future under various political, social-economic and environmental scenarios. Finally, the outcome of the analysis is not an answer to a single question, but rather a process which provides key insights concerning associative and causal linkages that have the potential to untangle and answer a wide range of questions on poverty and the environment (Chap. 28).

The research also describes a range of plausible future trajectories derived in a participatory manner. Hence, while the individual components of the analysis are interesting, the integration of these components is ground-breaking—for example, the integration of social differentiation in rural settlements with biophysical outputs to model poverty through time based on changes in the natural environment.

2.2.2 Social Mechanisms Co-vary with the Bundles of Ecosystem Services

This research dynamically analyses the two most important ecosystem services in terms of livelihoods in the delta: agriculture (including aquaculture where appropriate Chap. 24) and fisheries (focusing on offshore capture fisheries Chap. 25) under future environmental change and management scenarios. The area and species distribution of the Sundarbans mangrove forest are also modelled with a preliminary assessment of ecosystem services including protection against storm surges (Chap. 26). These three key provisioning services were operationalised using seven social-ecological systems, defined as freshwater and brackish aquaculture, irrigated and non-irrigated agriculture, riverine and char environments, the coastal zone and the Sundarbans dependent zone (see Chap. 22, Adams et al. 2013, 2016).

The social-ecological system classification recognises that although in certain regions a specific type of service may dominate livelihoods, households usually have more than one type of income source and that these sources may change through the year depending on the character of the ecosystem (Raudsepp-Hearne et al. 2010). Households select different ecosystem services from within the bundle at different times of the year. Social-ecological systems are thus the result of human activities to mediate the negative impacts of environmental variability and to manage bundles of ecosystem services (Martín-López et al. 2012). Social systems dictate the rules of access to resources and influence the winners and losers of trade-offs between different benefits (Walker et al. 2004), ultimately affecting the relationship between ecosystem service dependence and poverty outcomes.

The relationship between ecosystem services and poverty changes because social mechanisms and other factors co-vary with bundles of ecosystem services. For example, the presence of opportunities for supplementing incomes with open access resources (e.g. fisheries, forest products), land ownership, opportunities for sharecropping and leasing land, agricultural labour, access to off-farm income opportunities, the level of exposure to extreme events, the impacts of cyclones and storm

surges, the negative impacts on agriculture from aquaculture and the presence of landlords on whom the poor can rely for assistance through patron-client relationships all vary between social-ecological systems (see Adams and Adger 2016).

2.2.3 Spatial Variation in Ecosystem Services within Delta Environments

Assets, income, nutrition- and blood pressure-related health indicators and subjective well-being vary with location. Waterlogging, high salinity and access are significantly associated with poverty in the study area with different spatial patterns apparent for these three variables (see Chap. 21 and Amoako Johnson et al. 2016). Soil salinity is significantly associated with poverty around the Sundarbans, waterlogging in the centre of the study area, while the lack of access dominates in the east of the study area. For example, the factors associated with asset poverty vary across the study area. Considering all social-ecological systems, the probability of being materially and subjectively poor decreases as household dependence on ecosystem services for income increases. However, the irrigated agricultural zone showed the opposite relationship, with increasing dependence on ecosystem services being associated with a higher probability of being materially poor.

Similar spatial and social-ecological system-based differences are found in the health indicators (Chap. 27) and in how individuals perceive their own well-being. Levels of malnourishment are higher than the national average but vary across the study area. For example, food consumption varies across the study area and by social-ecological system. Irrigated agriculture areas show the lowest protein intake and one of the lowest calorie intakes. In comparison, households living in the char and rain-fed agricultural social-ecological systems also have low calorie intake levels, but the protein consumption (from fish) is much higher and child undernutrition lower. This indicates that fish consumption appears crucial to health in some social-ecological system.

2.2.4 Temporal Variations in Well-Being from Ecosystems

Ecosystem services vary by season and across years with implications for chronic and seasonal poverty. When examining past trends, three factors suggests that maintaining current productivity of agriculture and aquaculture will be challenging. First, historic analysis shows that recent increases in these provisioning services have been accompanied by concomitant decreases in underlying supporting services (see Chap. 5 and Hossain et al. 2016). Second, infrastructural interventions to facilitate increases in productivity of provisioning services (e.g. coastal embankments and polders) have caused a rigidity trap reducing flexibility in adaptation to future climate change (Adams et al. 2013). Third, seasonal changes (wet/dry seasons) in household livelihoods reflect changing work opportunities, leading to different long-term poverty trajectories (Lázár et al. 2016).

Since the 1950s, production of rice, shrimp and fisheries has increased consistently with gross domestic product (GDP) and per capita income (Hossain et al. 2016). However, this has been accompanied by a decrease in the quality of supporting services such as water quality and availability, natural hazard and erosion protection and maintenance of biodiversity, as well as availability of forest products. Thus, although provisioning ecosystem services of rice and agriculture have supported national level growth, it has been at the expense of the systems that support them (including potentially irrigation-induced salinisation of soil) and therefore may not be sustainable into the future (see Chap. 24).

During the 1990s, many provisioning and supporting ecosystem services declined (Hossain et al. 2016) linked to the modification of the natural functioning of rivers and their interaction with the floodplain. This includes tidal sediment deposition outside of the polders and drainage congestion within the polders (Islam 2006), while the interiors of polders have lost substantial elevation (e.g. Hoque and Alam 1997). It was these polders that initially enabled an increase in productivity by protecting the floodplain from inundation and, in turn, allowed the development of multi-cropping and aquaculture.

The longer-term future implications of such past and irreversible changes to the natural environment are problematic. For example, while productivity increases were enabled by this infrastructure, continued increases will be challenged under a future changing climate (Adams et al. 2014). Some of these problems may be ameliorated through upgrading the embankments but a more fundamentally sustainable long-term management technique such as controlled sedimentation within polders to build elevation, termed 'tidal river management' in Bangladesh (Amir et al. 2013; Auerbach et al. 2015), may be beneficial on a large scale. Looking into the future it is unclear whether an increase in GDP will eventually lead to the environmental investment necessary (i.e. following the environmental Kuznets curve, Hossain et al. 2016) to halt the further degradation of supporting services for agriculture.

Agricultural models of the delta (Chaps. 24 and 28) show that dry season productivity is currently constrained by salinity. Crop productivity may be maintainable to 2050 due to the positive impacts of projected increases in rainfall, temperature (within the range of rice) and CO_2 fertilisation. The constraining factors are fertility and heat stress if the monsoon season rains remain sufficient to remove salinity that has accumulated during the dry season. This, however, will be impacted in the longer term by sea-level rise, subsidence, dry season decreases in upstream flow and human water management (Chaps. 13, 16 and 17). Again tidal river management may be applied. A second crop could provide an additional income although income from wet season rice cultivation is constrained by low market prices.

Fisheries are second only to agriculture as a source of income in Bangladesh and form the main source of protein (Chap. 27). Offshore capture fisheries models (Chap. 25) project small decreases in overall fisheries productivity with climate change. It remains to be seen whether such decreases can be offset with sustainable management practices. However, the two most important fish species (Bombay duck and especially Hilsa) are susceptible to a potential collapse due to unsustainable fishing practices. This would intensify livelihood stress for subsistence fishers and emphasise the importance of sustainable exploitation of these resources.

A final way that temporal dimensions can provide answers as to why and when ecosystem services may be able to alleviate poverty emerges from analysis of long-term poverty trajectories, driven by day-to-day coping strategies and seasonal livelihood diversification. These trajectories have been characterised for a range of livelihood diversification strategies in a quantitative model (Lázár et al. 2016) based on survey data collected as part of this research (see Chap. 23 and Adams et al. 2016), household income and expenditure data and census data. Modelling livelihood trajectories for different archetypal households, with different seasonal livelihood strategies and multiple coping strategies during periods of low income, shows the transient nature of poverty and the ways in which farm and off-farm employment combine to create more or less stable well-being pathways. The analysis (see Chap. 28) shows that, while land ownership is crucial to avoid poverty, the poverty outcomes of small landowners are highly variable. Differences in micro-level choices therefore accumulate to create different outcomes for households with similar livelihood and poverty characteristics. The analysis also shows that most households have incomes that do not come from ecosystem services. Many households have two or three income sources, and almost all households show seasonal changes in their income type. Strategies vary, with different variations in income between seasons and different diversification strategies to maintain income. Modelling poverty trajectories in this way allows these seasonal drivers of long-term poverty dynamics to be integrated with other biophysical models to understand drivers of poverty at different scales and how poverty may change in the future under different interventions. Simulation results reveal the poverty alleviation role of off-farm income types and the importance of the quality of that off-farm employment, since households relying on small-scale, cottage industries are most likely to be poor and stay poor. These results support other studies that indicate land ownership is a necessary stepping stone out of poverty as it provides households with the capital to access high end off-farm income opportunities.

This research has therefore confirmed the need to consider ecosystem services for poverty alleviation in the wider context of agrarian reform. Many of the barriers to creating pro-poor ecosystem services-based livelihoods emerge from processes put into place during the ‘Green Revolution’—for

example, polders (Adams et al. 2014), and, more recently, the Blue Revolution of the aquaculture industry (Amoako Johnson et al. 2016). The judgement is whether any environmental degradation is justified for food security, national wealth objectives and the fair distribution of benefits.

2.2.5 Ecosystem Service Trade-offs between Social-Ecological Systems and Labour Mobility

Whether or not ecosystem services are a force for good in the diverse and dynamic delta environment of coastal Bangladesh relates to the nature of the trade-offs between different social-ecological systems. Trade-offs are an important part of the ecosystem service framework; for each service prioritised, another service will be diminished (Rodriguez et al. 2006). The same is true in the delta. Analysing past trends in the delta shows trade-offs between provisioning ecosystem services (that have been increasing) and the systems that support them (that have shown a consistent decline) (Hossain et al. 2016).

In the study area, trade-offs tended to work in a way that further concentrates rights to ecosystem services to those that already have them. For example, agriculture and aquaculture practices contribute to the degradation of the open access resources on which the landless depend, leaving them even further marginalised. This can be conceptualised by looking at the nature of the property rights system. Social-ecological systems where private property rights dominate, such as aquaculture, are most destructive to other systems. Ecosystem services from open access systems more readily co-exist. People react to changes in ecosystem services and there is a livelihood mobility dimension to any trade-offs between social-ecological systems. People move to alternative systems, or change jobs, to counteract the seasonality and irregularity of income from ecosystem services in one social-ecological system and when systems are degraded over the long term or labour is no longer required (e.g. as agricultural land is converted to agriculture employment declines significantly). Thus, migration of people between systems and livelihoods counters to the availability of ecosystem services.

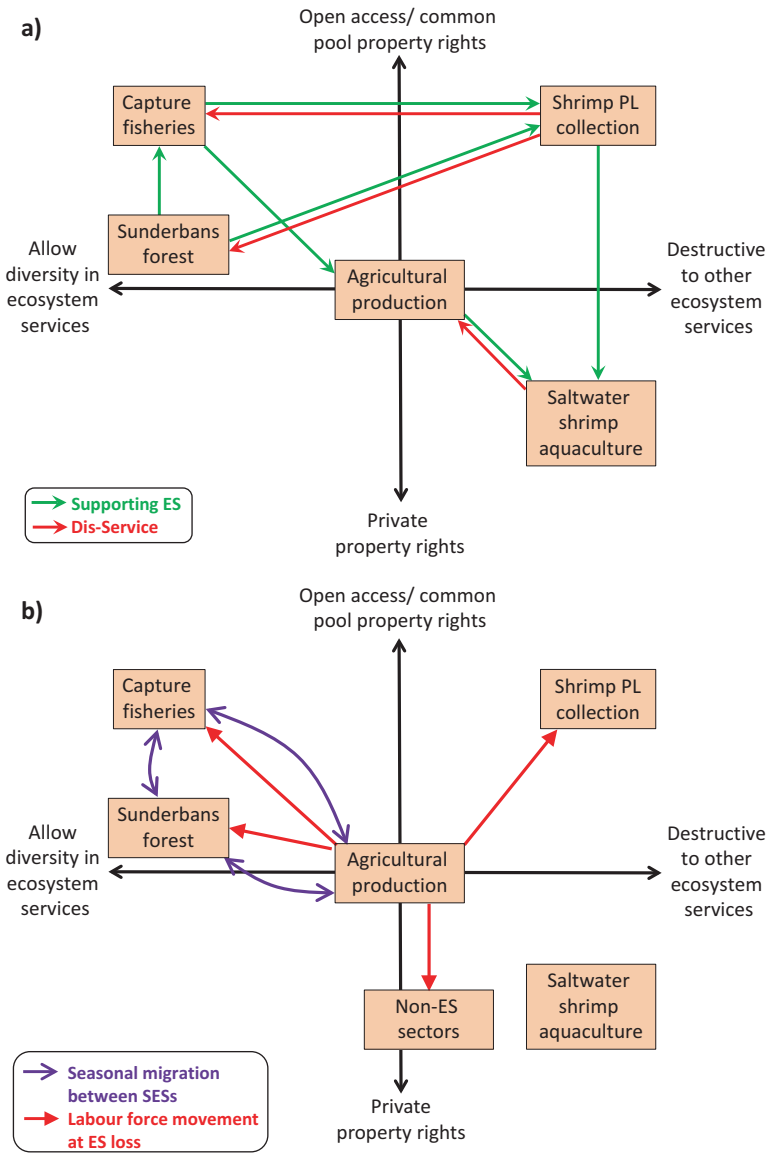

Fig. 2.1 Stylised representations of selected movements of people and trade-offs between ecosystem services, between social-ecological systems in the coastal zone of Bangladesh, geographically and between seasons. The y-axis represents the degree to which the services of that social-ecological system are privately owned. The x-axis represents whether the productivity of the social-ecological system is dependent on the degradation of another. Arrows show flows of labour, materials and process linkages. The diagrams illustrate the inter-dependent nature of social-ecological systems in the delta and the potential trade-offs in productivity and rural employability

Figure 2.1 illustrates some of the ways in which ecosystem services and benefits are transferred between different social-ecological systems across space and time, and the concurrent migration flows following livelihood opportunities. Ecosystem benefits, and thus people, move from one social-ecological system to another because of land use change and the transformation of one system to another, and seasonally. For example, where embankments protect the flood plain from inundation, those dependent on capture fisheries for livelihoods (e.g. traditional fishermen, boatmen for transportation) rely more heavily on the other social-ecological systems, move into off-farm opportunities or leave the area in search of economic opportunities. Therefore, labour is constantly moving between these different systems based on the season or the availability of resources.

Ecosystem services and benefits, or the capacity of a system to be productive, are also 'moving' between each system, the productivity of each social-ecological system being affected by the productivity of the others. The movement of ecosystem services between the systems is exemplified in the supply of wild shrimp larvae for pond aquaculture, sourced in the Sundarbans forest. While subsistence fishing exists without any detriment to the Sundarbans, this fry collection is a destructive process, not only to the Sunderbans where fish productivity is reduced because of bycatch but also in offshore fisheries, since the Sundarban forest supports nurseries for offshore fisheries by providing a supply of shrimp fry (Islam and Islam 2011). Thus the increase in productivity of shrimp farms has been at the expense of the Sundarbans biodiversity and productivity and the offshore fish catch.

2.3 Ecosystem Services in Changing Delta Agricultural Economies

The ability of rural populations in deltas to use ecosystem services for poverty alleviation is a function of the productivity of the ecosystem services, access and entitlements to those services, prior infrastructural or policy interventions and the dynamics of the diverse social-ecological systems. Specific ecosystem services are important for poverty alleviation

because they have higher market value or are more abundant. However, a route out of poverty depends on the combination of pre-existing access levels and entitlements and the mix of different bundles of ecosystem services available over time and space.

The decades of rural development aimed at increasing agricultural productivity across deltas in South Asia have left certain populations behind. There are poor rural populations who have been unable to access the economic benefits that have accompanied integration into the market economy (e.g. Rigg 2006) and thus rely on increasingly degraded open access resources (e.g. fisheries) or precarious forms of off-farm employment (e.g. small-scale manufacturing or cottage industries). Households living in rural areas without the safety net provided by ecosystem services are doubly vulnerable: exposed to volatile markets and globalisation processes, but without the safety net of basic subsistence. Ecosystem services for poverty alleviation therefore must be analysed in the wider context of agrarian change. Worldwide, agriculture and resource-based local economies are diversifying (Bebbington 2000; Rigg 2006). As a result, solutions to poverty alleviation within rural societies typical of the Bangladesh delta are unlikely to lie solely within the realms of ecosystem services.

For the Ganges-Brahmaputra-Meghna delta, perhaps by contrast and as shown throughout this research, reliance on ecosystem services remains important both for poverty prevention and potentially for poverty alleviation. The lack of development of a range of sophisticated off-farm opportunities (World Bank 2016) may contribute to this as the poorest in the study area are those dependent on small-scale manufacturing ('cottage' industries) (Chap. 23). Furthermore, levels of migration, the means by which rural lives have been able to continue across much of south Asia, are low within the population surveyed (around 15 per cent of households had a migrant currently or in the past four months). Agriculture continues to be the lynchpin of the rural economy in Bangladesh (World Bank 2016), something that the findings of this research support. Thus, perhaps those in poverty are experiencing the worst of both worlds—the loss of traditional, subsistence-based ecosystem service use, without the benefits of market integration.

2.4 Conclusion

Access to ecosystem services continues to be the lynchpin of well-being in deltaic rural areas in Bangladesh, yet access to these services is diminishing for the poor. Current patterns of winners and losers from development processes are persistent, and ecosystem services are unlikely to lift the rural poor out of poverty without a complete restructuring of social and economic relations in rural areas. If this is the case, future ecosystem service research should focus on pro-poor, environmentally sustainable and rural development opportunities.

Yet, dynamic changes in the relationship between ecosystem services and poverty are apparent, and thus past or present relationships may not be a good guide to understanding the future (see Chap. 28). The availability of ecosystem services may change radically due to external forces, potentially remote from the delta's ecosystem services, such as (i) upstream flows from India and beyond (Chap. 13), (ii) global sea-level rise (Chap. 14), shifts in global and regional markets (Chap. 12) and (iii) changing demography (Chap. 19). Furthermore, Bangladesh is moving towards a more urbanised future, where a diminishing proportion of the population of delta areas will be directly reliant on ecosystem services for their livelihoods (Banks et al. 2011). Thus, future problems may revolve around enabling and improving access of the poor, urban populations to ecosystem services, either within the city or virtually through, for example, food networks to ensure minimal levels of well-being.

Fundamentally, the ability of ecosystem services to meet poverty alleviation objectives must be placed within broader questions of sustainability of rural areas, alternative economic systems, population growth and the impacts of extreme environmental change. Systems-based and modelling approaches, as exemplified in this research, are well-suited to explore such dynamic, multi-scalar and potentially non-linear relationships.

References

Adams, H., and W.N. Adger. 2016. Mechanisms and dynamics of wellbeing-ecosystem service links in the southwest coastal zone of Bangladesh. UK Data Service Reshare. https://doi.org/10.5255/UKDA-SN-852356.

Adams, H., W.N. Adger, H. Huq, R. Rahman, and M. Salehin. 2013. Wellbeing-ecosystem service links: Mechanisms and dynamics in the southwest coastal zone of Bangladesh. ESPA Deltas working paper 2. Southampton: University of Southampton. www.espadelta.net/resources_/working_papers/. Accessed 12 Dec 2016.

———. 2014. Transformations in land use in the southwest coastal zone of Bangladesh: Resilience and reversibility under environmental change. In *Proceedings of transformation in a changing climate*, June 19–21. Oslo, Norway.

Adams, H., W.N. Adger, S. Ahmad, A. Ahmed, D. Begum, A.N. Lázár, Z. Matthews, M.M. Rahman, and P.K. Streatfield. 2016. Spatial and temporal dynamics of multidimensional well-being, livelihoods and ecosystem services in coastal Bangladesh. *Scientific Data* 3: 160094. https://doi.org/10.1038/sdata.2016.94.

Adger, W.N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27 (2): 249–269.

Agrawal, A. 2005. Environmentality: Technologies of government and the making of subjects. In *New ecologies for the twenty-first century*, ed. A. Escobar and D. Rocheleau. Durham: Duke University Press.

Amir, M.S.I.I., M.S.A. Khan, M.M.K. Khan, M.G. Rasul, and F. Akram. 2013. Tidal river sediment management-A case study in southwestern Bangladesh. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering* 7 (3): 176–185.

Amoako Johnson, F., C.W. Hutton, D. Hornby, A.N. Lázár, and A. Mukhopadhyay. 2016. Is shrimp farming a successful adaptation to salinity intrusion? A geospatial associative analysis of poverty in the populous Ganges–Brahmaputra–Meghna Delta of Bangladesh. *Sustainability Science* 11 (3): 423–439. https://doi.org/10.1007/s11625-016-0356-6.

Auerbach, L.W., S.L. Goodbred, D.R. Mondal, C.A. Wilson, K.R. Ahmed, K. Roy, M.S. Steckler, C. Small, J.M. Gilligan, and B.A. Ackerly. 2015. Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain. *Nature Climate Change* 5 (2): 153–157. https://doi.org/10.1038/nclimate2472.

Banks, N., M. Roy, and D. Hulme. 2011. Neglecting the urban poor in Bangladesh: Research, policy and action in the context of climate change. *Environment and Urbanization* 23 (2): 487–502. https://doi.org/10.1177/0956247811417794.

Bebbington, A. 2000. Reencountering development: Livelihood transitions and place transformations in the Andes. *Annals of the Association of American Geographers* 90 (3): 495–520. https://doi.org/10.1111/0004-5608.00206.

Dempsey, J., and M.M. Robertson. 2012. Ecosystem services: Tensions, impurities, and points of engagement within neoliberalism. *Progress in Human Geography* 36 (6): 758–779. https://doi.org/10.1177/0309132512437076.

Gunderson, L.H., and C.S. Holling, eds. 2002. *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.

Hartmann, B., and J.K. Boyce. 1983. *A quiet violence: View from a Bangladesh village*. London: Zed Books.

Hayami, Y., and M. Kikuchi. 2000. *A rice village saga: Three decades of green revolution in the Philippines*. London/Lanham: Macmillan Press/Barnes & Noble.

Hoque, M., and M. Alam. 1997. Subsidence in the lower deltaic areas of Bangladesh. *Marine Geodesy* 20 (1): 105–120. https://doi.org/10.1080/01490419709388098.

Hossain, M.S., J.A. Dearing, M.M. Rahman, and M. Salehin. 2016. Recent changes in ecosystem services and human well-being in the Bangladesh coastal zone. *Regional Environmental Change* 16 (2): 429–443. https://doi.org/10.1007/s10113-014-0748-z.

Islam, M.R. 2006. Managing diverse land uses in coastal Bangladesh: Institutional approaches. In *Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts*, ed. C.T. Hoanh, T.P. Tuong, J.W. Gowing, and B. Hardy. Wallingford: CAB International.

Islam, K.M., and M.N. Islam. 2011. Economics of extraction of products from Sundarbans reserve forest. *Bangladesh Journal of Agricultural Economics* 34 (1/2): 29–53.

Lázár, A.N., H. Adams, W.N. Adger, and R.J. Nicholls. 2016. *Characterising and modelling households in coastal Bangladesh for model development*. Project working paper. ESPA Deltas, University of Southampton. www.espadelta.net.

Leach, M., R. Mearns, and I. Scoones. 1999. Environmental entitlements: Dynamics and institutions in community-based natural resource management. *World Development* 27 (2): 225–247. https://doi.org/10.1016/s0305-750x(98)00141-7.

Martín-López, B., I. Iniesta-Arandia, M. García-Llorente, I. Palomo, I. Casado-Arzuaga, D. García Del Amo, E. Gómez-Baggethun, E. Oteros-Rozas,

I. Palacios-Agundez, B. Willaarts, J. González, F. Santos-Martín, M. Onaindia, C. López-Santiago, and C. Montes. 2012. Uncovering ecosystem service bundles through social preferences. *PLoS One* 7 (6): e38970. https://doi.org/10.1371/journal.pone.0038970.

Nicholls, R.J., C.W. Hutton, A.N. Lázár, A. Allan, W.N. Adger, H. Adams, J. Wolf, M. Rahman, and M. Salehin. 2016. Integrated assessment of social and environmental sustainability dynamics in the Ganges-Brahmaputra-Meghna delta, Bangladesh. *Estuarine, Coastal and Shelf Science* 183: 370–381. https://doi.org/10.1016/j.ecss.2016.08.017. Part B.

Ostrom, E. 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.

Raudsepp-Hearne, C., G.D. Peterson, and E.M. Bennett. 2010. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences of the United States of America* 107 (11): 5242–5247. https://doi.org/10.1073/pnas.0907284107.

Rigg, J. 2006. Land, farming, livelihoods, and poverty: Rethinking the links in the Rural South. *World Development* 34 (1): 180–202. https://doi.org/10.1016/j.worlddev.2005.07.015.

Robbins, P. 2011. *Political ecology: A critical introduction*. 2nd ed. Chichester: Wiley.

Rodriguez, J.P., T.D. Beard, E.M. Bennett, G.S. Cumming, S.J. Cork, J. Agard, A.P. Dobson, and G.D. Peterson. 2006. Trade-offs across space, time, and ecosystem services. *Ecology and Society* 11 (1): 28. www.ecologyandsociety.org/vol11/iss1/art28/.

Scoones, I. 1998. Sustainable rural livelihoods: A framework for analysis IDS Working paper 72. Brighton: Institute of Development Studies (IDS). http://www.ids.ac.uk/files/dmfile/Wp72.pdf. Accessed 11 July 2017.

Walker, B., C.S. Holling, S.R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in socio-ecological systems. *Ecology and Society* 9 (2): 5. www.ecologyandsociety.org/vol9/iss2/art5/.

World Bank. 2016. Dynamics of rural growth in Bangladesh : Sustaining poverty reduction. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/24369. Accessed 11 July 2017.